Mission and Science Measurement Technology (MSM) Theme

NASA Computing, Information, and Communications Technologies (CICT) Program

Information Technology Strategic Research (ITSR) Project

Intelligent Controls and Diagnostics (ICD) Sub-Project and NeuroElectric Machine Control (NeMC) Sub-Project

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ARC Confirms:	G. Scott Hubbard, ARC Director	Date
ITSR Submitted:	Joseph Totah, ICD/NeMC Sub-Project Manager	Date

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1 PURPOSE

Intelligent Controls and Diagnostics (ICD) and NeuroElectric Machine Control (NeMC) are sub-projects under the Information Technology Strategic Research (ITSR) Project. The objectives of ICD are to improve component/subsystem safety and system survivability. The objectives of NeMC are to improve integrated human/system performance, as well as reduce development time and operational cost. The approach in ICD is to develop adaptive flight control systems that automatically compensate for failures or damage that would otherwise result in a catastrophic event, develop predictive component/subsystem diagnostic methods to detect and isolate imminent component malfunctions well in advance of a failure, and develop outer-loop technologies to intelligently maneuver a vehicle under nominal and off-nominal conditions. The approach in NeMC builds upon the system-level approach in ICD by developing machine learning algorithms to tighten the control loop and provide a new computer interfacing modality in immersed human machine systems.

2 OVERVIEW

Many of the technologies in ICD are developed for aircraft, launch vehicles, and spacecraft applications (piloted, remotely operated, and autonomous). The technologies in NeMC will have broader applications to in-space construction and the associated interaction with robotic devices. The intent is to leverage information technologies and core competencies in soft computing and computational intelligence to support specific objectives within NASA's Strategic Plan. The value added to NASA's missions resulting from an investment in these sub-projects are to improve safety, reduce cost (during design/development and operation), increase efficiency, and extend operational life for flight critical components, subsystems, overall vehicle, and fully integrated human/machine systems.

3 DETAILED SUB-PROJECT OBJECTIVES

The detailed sub-project objectives are aligned with the NASA Strategic Plan, and directly correspond to CICT Program and ITSR Project milestones that are quantifiable and measurable.

The ICD objectives support the following 2003 NASA Strategic Plan Mission and Goal:

Mission 1: Understand and protect our home planet
Goal #3: Create a more secure world and improve the quality of life by investing in technologies and collaborating with other agencies, industry, and academia.

> *"NASA works collaboratively with the Department of Defense to develop technologies and systems that help keep U.S. military aviation and space capabilities the most advanced in the world"*.

ICD Objectives:

a. Develop adaptive flight control systems that automatically compensate for failures or damage (to the extent possible) that would otherwise result in a catastrophic event (ref. ITSR project milestone 8.4).
b. Integrate health management and diagnostics technologies to detect, isolate, and rectify imminent component malfunctions and extend component/subsystem life (ref. ITSR project milestone 8.6).
c. Design outer-loop methods to intelligently maneuver a vehicle under nominal and off-nominal conditions (ref. ITSR project milestone 8.11).

The NeMC objective supports the following 2003 NASA Strategic Plan Mission and Goal:

Space Flight Capabilities
Goal 10: Enable revolutionary capabilities through new technologies.

> *"When human explorers venture into the solar system, they will be supported by a wide array of technologies for life support, information management, and scientific exploration. They also will operate in concert with robotic vehicles and devices that serve as their assistants and exploration partners. Today, we are planning and developing new technologies that will enable safe and efficient human exploration and <u>optimize this human-robotic partnership</u>."*

NeMC Objective:

d. Develop neuro-electric machine control algorithms to tighten the control loop and provide new computer interfacing modalities in immersed systems (ref. ITSR project milestone 8.12).

Below are the Project and Sub-Project milestone definitions corresponding to (a)-(d), and their associated metrics:

a. 8.4 Demonstrate a simplified adaptive flight control system that exhibits equivalent or improved levels of safety and handling qualities following damage. (4QFY05)
   Improved Level of Handling Qualities Following Damage:
   SOA=CH-2
   Planned Value=CH-1
   Units of Measure: Cooper-Harper (CH) Rating Scale

b. 8.6 Demonstration of propulsion health management technologies for engine performance enhancement and component health and safety monitoring. (2QFY05)
   Improved Health and Usage Monitoring and Engine Hot Section Life Cycle (LC) Extension:
   SOA=50 KHz, Vibration
   Planned Value=75KHz, Vibration + Oil Debris.
   SOA=0% LC
   Planned Value=20%
   Units of Measure: Monitoring frequency and percent LC improvement for engine hot section

c. 8.11 Demonstrate an intelligent maneuvering system capable of incorporating planning and decision-making models to give the vehicle goal directed self-reliant behavior with a high degree of autonomy. (4QFY06)
   Strategic and Tactical Maneuvering Under off-Nominal Conditions:
   SOA=ACL 3 (2004)
   Planned Value= ACL 4
   Units of Measure: Autonomous Control Level (ACL) Trend Referenced in the 12/02 DoD UAV Roadmap

d. 8.12 Demonstration of novel computational methods for neuro-electric machine control capabilities using EMG and EEG signals for closed-loop control, and human augmentation. (4QFY06)
   NeuroElectric Interfaces (Improved Human Communication, Monitoring and Control)
   SOA=non-real-time
   Planned Value=near real-time
   Units of Measure: Speed of acceptable pattern recognition

Detailed Task Objectives are provided in the Level 4 Task Plans.

4 PROJECT MANAGEMENT OVERVIEW

The CICT research program has program responsibility at NASA HQ. The Office of Aerospace Technology Enterprise Program Management Council (EPMC) has CICT governing responsibility. The Enterprise official is Victor Lebacqz, Acting Associate Administrator for Aerospace Technology at HQ. The Theme Director is Chris Moore, Acting Director for Mission and Science Measurement (MSM) Technology at HQ. The Program Manager and point of contact for CICT is Eugene Tu. Management of the CICT ITSR Project has been delegated to the Ames Research Center. David Alfano is the ITSR Project Manager.

4.1 Organization

The Program, Project, and Sub-Project-level management structure is defined in the following organization chart:

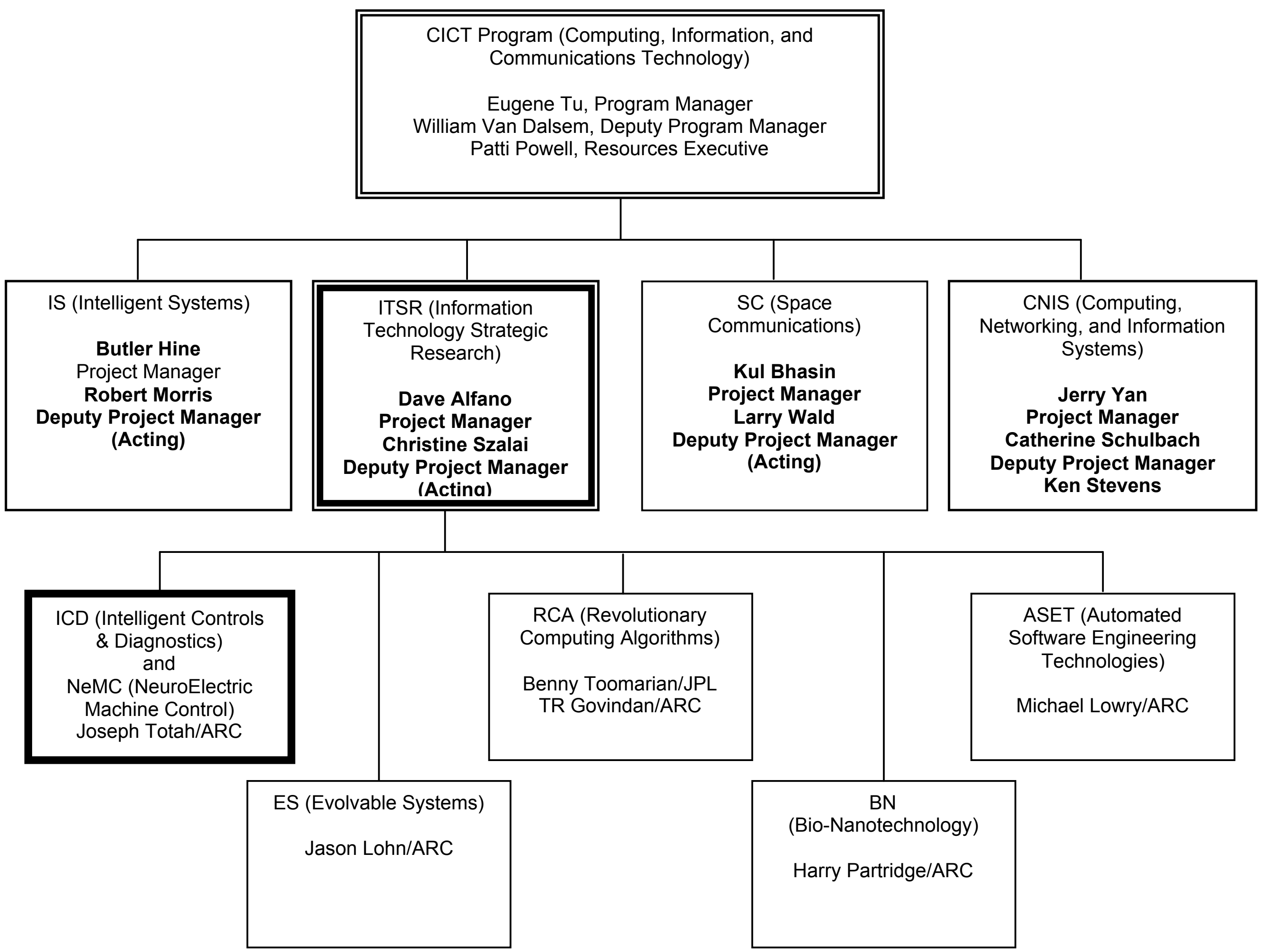

Figure 4-1 ITSR Organization Chart

4.2 Detailed Sub-Project Work Breakdown Structure

The Task-Level Work Breakdown Structure (WBS), and the associated Centers and/or partners with whom associated management authority resides, is as follows:

Intelligent Controls and Diagnostics
Joseph Totah, Sub-Project Manager, ARC

> Intelligent Health and Safety Monitoring
> Dr. Edward Huff, Task Lead, ARC
>
> Intelligent Controls and Diagnostics for Propulsion Systems
> Donald Simon, Task Lead, GRC
>
> Intelligent Flight Control
> Dr. Kalmanje KrishnaKumar, Task Lead, ARC
>
> Intelligent Automation
> John Kaneshige, Task Lead, ARC

NeuroElectric Machine Control
Joseph Totah, Sub-Project Manager, ARC
Dr. Kevin Wheeler, Task Lead, ARC

5 TECHNICAL COMMITMENT

The Project Milestones for ICD and NeMC comprise the technical commitment. These milestones are summarized are as follows:

8.4 (4QFY05) - Demonstrate a simplified adaptive flight control system that exhibits equivalent or improved levels of safety and handling qualities following damage.

8.6 (2QFY05) - Demonstration of propulsion health management technologies for engine performance enhancement and component health and safety monitoring.

8.11 (4QFY06) - Demonstrate an intelligent maneuvering system capable of incorporating planning and decision-making models to give the vehicle goal directed self-reliant behavior with a high degree of autonomy.

8.12 (4QFY06) - Demonstration of novel computational methods for neuro-electric machine control capabilities using EMG and EEG signals for closed-loop control, and human augmentation.

5.1 Technical Specifications (Project/Sub-Project Milestones)

This section shows Project and Sub-Project milestones and metrics, and comprises the technical commitment to ITSR. Dependencies exist for milestones 8.4 and selected supporting milestones, such that the Vehicle Systems Program funds in-flight validation on the NASA Dryden F-15 (Tail number 837) aircraft. A dependency exists for milestone 8.6 and selected supporting milestones, such that the Vehicle Systems Program funds in-flight data collection and in-flight validation on USAF C-17 T1 aircraft.

***Project*/Sub-Project Milestones**	**Due Date**	**Metrics**
8.4 Demonstrate a simplified adaptive flight control system that exhibits equivalent or improved levels of safety and handling qualities following damage.	*Sep-05*	*Flight test results demonstrating a simplified adaptive flight control system provides equivalent or improved levels of safety and handling qualities following damage without the requirement for on-line parameter identification and/or other computationally expensive components. An adaptive flight control technique that is less complex, easier to implement, and can be retrofitted to existing flight control laws in modern aircraft.*
8.4.1 Preliminary design review of the simplified adaptive flight control system.	Jul-03	Analysis of the system performance, including simulation results under nominal and failure conditions. Final Technology Readiness Review (TRR) to be conducted at NASA Dryden Flight Research Center.

***Project*/Sub-Project Milestones**	**Due Date**	**Metrics**
8.4.2 Hardware in the loop testing of the simplified adaptive flight control system.	Jan-04	Verified flight software, including all safety monitors, failure insertion routines, and data acquisition systems. Test results showing that the system is cleared for in-flight evaluation.
8.4.3 First flight demonstration of a simplified adaptive flight control system that exhibits equivalent or improved levels of safety and handling qualities following damage.	Sep-04	First flight demonstrating a simplified adaptive flight control system provides equivalent or improved levels of safety and handling qualities following damage without the requirement for on-line parameter identification and/or other computationally expensive components. An adaptive flight control technique that can be validated across a Class B Envelope (reversionary, clean up-and-away) under nominal and simulated failure conditions.
8.4.4 Post flight test analysis, reporting, and outreach.	Sep-05	Final report on flight test demonstrations, and print/multi-media development for educational outreach and external affairs. NASA Technical Memorandum or NASA Technical Paper documenting the approach, methodology, and analytical/experimental results that can be used as a substantive reference upon which future work can build upon. A conference paper and/or journal article in a relevant professional forum will also be developed and prepared and presented so that the results can be shared with the technical community at large.

***Project*/Sub-Project Milestones**	**Due Date**	**Metrics**
8.6 Demonstration of propulsion health management technologies for engine performance enhancement and component health and safety monitoring.	*Sep-06*	*(1) An adaptive control system for turbine casing cooling flow to accommodate the effect of engine degradation on turbine clearance. Maintain design efficiency of the turbine as the engine degrades by maintaining the clearances to the design level, resulting in increased engine life due to reduction in rate of exhaust gas temperature degradation and consistent performance over the engine life. (2) Development of HealthWatch III (HW-3) including a programmable data acquisition system and the ability to sample and store high-speed data in operation. A health monitoring system for integrated real-time sampling of both vibration and oil-debris signals for advanced damage detection of incipient component degradation.*
8.6.1 Engine simulation demonstration of smart life extending control using stochastic based life models.	Sep-03	The engine control will adapt to current engine condition with the objective to minimize future damage accumulation. Improved engine control will result in increased engine on-wing life and reduction in maintenance cost.
8.6.2 Demonstrate in-flight vibration monitoring module for mechanically geared engines and transmissions.	Sep-04	Demonstration of HealthWatch II (HW-2) health monitoring system. In-flight data acquisition capability that includes revolution counting and discontinuous time synchronous averaging features essential for the development and use of similar capabilities on transport aircraft for advanced engine monitoring.
8.6.3 First flight demonstration of health management technologies for subsystem performance enhancement and component health and safety monitoring.	Sep-05	First flight demonstration of HealthWatch III (HW-3), including a programmable data acquisition system and the ability to sample and store high-speed data in operation. First flight data collected from both vibration and oil-debris.

***Project*/Sub-Project Milestones**	**Due Date**	**Metrics**
8.6.4 Post flight test analysis, reporting, and outreach.	Sep-06	Final report on flight test demonstrations, and print/multi-media development for educational outreach and external affair. NASA Technical Memorandum or NASA Technical Paper documenting the approach, methodology, and experimental/experimental results that can be used as a substantive reference upon which future work can build upon. A conference paper and/or journal article in a relevant professional forum will also be presented so that the results can be shared with the technical community at large.
8.11 Demonstrate an intelligent maneuvering system capable of incorporating planning and decision-making models to give the vehicle goal directed self-reliant behavior with a high degree of autonomy.	*Sep-06*	*1) An intelligent maneuvering system that incorporates long-term planning to meet mission objectives, within mission constraints and performance limitations, while incorporating vehicle performance assessments and accommodating other unforeseen circumstances. 2) A system capable of performing time-critical flight path operations, which includes aggressive maneuvers in the presence of unexpected obstacles, by selecting discrete flight modes and targets in order to achieve strategic maneuvering objectives. The development of an intelligent maneuvering system capable of carrying out defined flight-path goals for a wide range of piloted and uninhabited vehicle classes, including fixed-wing, rotorcraft, and reusable launch vehicles. Success criteria will be the ability of the system to achieve equivalent pilot performance.*

***Project*/Sub-Project Milestones**	**Due Date**	**Metrics**
8.11.1 Integrate capabilities of diagnostics and control with multimodal interface.	Mar-05	A health management system capable of managing multi-level failures, and identify and limit the propagation of cascading failures. Success criteria are that failures must be prioritized by criticality so that saturation and shutdowns can be avoided, allowing a degraded system to complete its mission. A health management system capable of communicating to a Goal Executive, which in turn will provide the coordination of Intelligent Maneuvering system. System status will be relayed to the pilot through multimodal pilot interfaces.
8.11.2 Perform maneuver selection tests in a simulated environment for UAV applications.	Jun-06	Evaluate decision-making in the presence of internal and external disturbances. Maneuver selection effectiveness equivalent to that of a human operator/pilot.
8.12 Demonstration of novel computational methods for neuro-electric machine control capabilities using EMG and EEG signals for closed-loop control, and human augmentation.	*Sep-06*	*Demonstrations of neuro-electric machine control capabilities including: a) using EMG to control a graphical simulation in a closed-loop simulation, b) using EEG for augmenting human cognitive performance, c) report of novel biological and physics inspired pattern recognition technology. Feasibility determinations of the strengths of bioelectric signals that can be used for device control and human performance augmentation for use in Aeronautics, space-based or commercial applications. Success metrics will be the ability of the technology to operate in near-real time tasks such as database queries and complex monitoring or control tasks. Performance tests of the new pattern recognition algorithms.*
8.12.1 Determination of EMG patterns associated with sub-vocal patterns, EEG patterns associated with cognitive function, and computational performance of new biological and physics inspired pattern recognition algorithms.	Mar-05	A research report on the statistical analysis of patterns and recognition performance. Statistical and performance descriptions.

***Project*/Sub-Project Milestones**	**Due Date**	**Metrics**
8.12.2 Preliminary demonstration of novel computational methods for neuro-electric machine control capabilities using EMG and EEG signals for closed-loop control, and human augmentation.	Sep-06	First demonstration of EMG/EEG neuro-electric machine control capabilities. First performance tests of the new pattern recognition algorithms.

6 SCHEDULE

The schedule of due dates for ICD and NeMC milestones is provided in Section 5.

7 ACQUISITION STRATEGY & PERFORMING ORGANIZATIONS

Free and open competition will be used for acquiring hardware and services in support of the research. Procurement and technical monitoring of contracts and grants is performed at the NASA Center responsible for the specific tasks requiring the procurement.

The acquisition strategy for ICD and NeMC uses the following approach:

- External Contracts with companies and small businesses
- University Grants for research
- Internal Performance-Based Contracts for in-house R&D support

The current acquisition and agreements status is as follows:

<u>Space Act Agreements:</u>
QUASAR Corporation

<u>Collaborations and/or Cooperative Agreements:</u>
Boeing Phantom Works
DARPA
U.S. Army (Aeroflight Dynamics Directorate)
U.S. Air Force (C-17 SPO)

<u>Internships:</u>
Foothill/DeAnza (Student Interns)
U.C. Davis (Co-op Program)
National Research Council (Postdoctorate)

<u>Grants:</u>
University of Alabama
University of Connecticut
UC Santa Cruz
University of Texas, San Antonio (HIS)

<u>Contracts:</u>
General Electric
Pratt and Whitney
Honeywell
R&D support (QSS, Signal Processing Associates)

<u>SBIR/STTR</u>:
Qualtech Systems, Inc.
  University of Connecticut

Accurate Automation Corporation
University of Alabama

8 AGREEMENTS

Sponsored research is conducted by several universities and contractors funded by the specific research elements within the Sub-project. Major grants (recently completed, existing and planned) include Cleveland State University, Penn State University, University of Missouri-Rolla, University of Alabama, University of Connecticut, UC Davis, UC Santa Cruz, and the University of Texas, San Antonio. Major contracts include General Electric Aircraft Engines and Pratt & Whitney. Performance-based contracting is primarily through QSS Group Inc, and includes a subcontract with California Signal Processing Associates. A Reimbursable Space Act Agreement also exists between NASA Ames and Quantum Applied Science and Research Inc. Leveraged research through Phase II STTRs exist with Accurate Automation Corporation and Qualtech Systems Inc. There is also close collaboration with Boeing Phantom Works (St. Louis and Long Beach) on Intelligent Flight Control as part of the F-15 and C-17 flight test activity, and Honeywell on Intelligent Automation as part of the Space Launch Initiative.

Internal:

ITSR/ICD—MOA between NASA Ames and NASA Dryden: "F-15 and C-17 Intelligent Flight Control Experiments/Letter of Intent" (December 15, 2000).

ITSR/ICD—MOA, DFRC-190, between NASA Dryden and the C-17 SPO: "Use of a C-17 Aircraft to Support NASA Flight Research Programs" (May 20, 1999).

CICT/ITSR & ECS & Flight Research Program: Intelligent Flight Control Technology Development Agreement (under development)

External:

ITSR/ICD—Contract with General Electric Aircraft Engines for a one-year study to explore all potential schemes to extend engine life.

ITSR/ICD—Phase II STTR Contract for Onboard and Remote Vehicle Health Management.

ITSR/ICD—Phase II STTR Contract for Intelligent Control for Autonomous Remote Spacecraft.

ITSR/ICD—Reimbursable Space Act Agreement Between NASA Ames Research Center and Quantum Applied Science and Research Inc. for Evaluation of Capacitive Electrodes for Electrodes for Neuroelectric Readout and Their Derivative Applications.

9 RISK MITIGATION OVERVIEW

Continual risk management will be conducted through annual updates of the sub-project plans and the approval process. De-scope options at the task level will be identified and presented when necessary to the Sub-Project Manager. Any requests for de-scope options subsequent to the approval of the project plan that involve impacts to the near term project/program level milestones or reductions in resource allocation from supporting programs will be coordinated with those other programs and centers. Any de-scope options or proposals that are made as part of the annual update to the sub-project plan will be explained prior to the request for sign off of the plan.

Technical risk will be managed by the tasks. The risk items will be identified, with impacts based upon the following elements: technical development, resources loading, schedule and cost. The following shall be included, but not limited to, in the examination for each risk element:

a. Description of the element or event and assessed level or risk
b. Description of the consequences or impacts to the project
c. Characterization of risk
d. Mitigation Plans
e. Analysis of lessons learned from similar activities

Risk exists within every sub-project whether that risk is technical, in terms of achieving certain performance levels, or programmatic, in the form of potential time or financial deficits. Most of these risks will be managed with the particular tasks by reallocation of funds, workforce changes, redirection of research activities and/or by de-scoping the tasks. Decisions will be based on the technologies most critical to the program goals and milestones. Input for these decisions will result from project status reviews and interaction with customers, stakeholders and partners. An ongoing risk management approach will be employed that will be consistent with NASA NPG 7120.5B.

10 INDEPENDENT REVIEWS

Independent reviews are coordinated with, and in full compliance of those defined in the ITSR Project Plan. Independent reviews for ICD and NeMC that take place throughout the duration of performance are as follows:

a. Aerospace Technologies Advisory Committee (External)
   Every 6 months
   Coverage: All Tasks
   Review board selection: NASA HQ
   Reporting: Formal (Programmatic review on status, approach, and accomplishments)
   Effectiveness: yes
   Can results potentially influence research directions: yes

b. National Research Council Review (External)
   Every 2 years
   Coverage: All Tasks
   Review board selection: NASA HQ
   Reporting: Formal (Technical quality and relevance)
   Effectiveness: yes
   Can results potentially influence research directions: yes

c. Independent Implementation Review (IPAO)
   Periodic, typically annual
   Coverage: All Tasks
   Review board selection: NASA HQ
   Reporting: Formal (Programmatic quality and relevance)
   Effectiveness: yes
   Can results potentially influence research directions: yes

d. AIAA Intelligent Systems Technical Committee
   Biannual
   Coverage: All Tasks
   Committee selection: http://www.aiaa.org/about/index.hfm?abo=530
   Reporting: Annual report in Aerospace America
   Effectiveness: yes
   Can results potentially influence research directions: yes

e. Workshops and Meetings: Propulsion Control and Health Management (PCHM) Workshop, AHST/CICT Technical Interchange Meeting, Vehicle Systems (VS) Workshop (Cincinnati and Phoenix), New Millennium Program (NMP) Workshop in Washington, D.C., NATO UAV Workshop, Von Karman Lecture Series (2002 chair in ICD), Augmented Cognition Technical Interchange Experiment and Workshop

Annual
Coverage: All Tasks
Participant selection: PCHM restricted to NASA/DoD, VS open to industry, NMP invitation only
Reporting: minutes and action items (ad hoc)
Effectiveness: yes
Can results potentially influence research directions: yes

f. Line Management Reviews:
Monthly and quarterly
Coverage: All Tasks
Review Board Selection: Senior Management Council at ARC and GRC
Reporting: formal action item log
Effectiveness: yes
Can results potentially influence research directions: yes

g. Peer Reviewed Journal Publications, Conference Papers, and Patents
Often
Coverage: All Tasks
Review selection: Journal editor/associate editor, NASA peer review, Patent council review
Reporting: Technical Journals, Proceedings, and Patent Awards
Effectiveness: yes
Can results potentially influence research directions: yes

11 BUDGET

Intelligent Controls and Diagnostics Full Cost Budget by Center	FY2004	FY2005	FY2006	FY2007	FY2008	FY2009
Budget Authority (PY $ in Millions)	**8.9**	**0.4**	**0.0**	**0.0**	**0.0**	**0.0**
ARC	7.3					
GRC	1.7	0.4				

NeuroElectric Machine Control Full Cost Budget by Center	FY2004	FY2005	FY2006	FY2007	FY2008	FY2009
Budget Authority (PY $ in Millions)	**1.7**	**3.9**	**7.2**	**0.0**	**0.0**	**0.0**
ARC	1.7	3.9	6.3			
GRC			1.0			

12 CUSTOMER ADVOCACY & DEFINITION

Customer advocacy and definition are strengths of the ICD and NeMC Sub-Projects. Task Managers are responsible for developing technology based on customer needs, and work closely with other NASA Programs, Industry, Academia, and other Government Agencies within the aerospace community in this regard. Technology infusion is accomplished via critical path deliverables of the milestones themselves to those external organizations and Programs. Exit criteria are the metrics (output and outcome) defined for each Milestone (see DETAILED SUB-PROJECT OBJECTIVES section), which are mapped directly into the 2003 NASA Strategic Plan. The satisfaction of the technology benefactor, and the method upon which it is determined is delegated to the Task Managers.

13 CONTROLS

Program control is shown in the table below. The reports and reviews described in this table track are designed to track both technical and financial performance.

Type	Frequency	Purpose	Reporting By	Content/Format	Comments
Monthly Progress	4-weeks/ monthly	Monthly Progress Report (MPR); HQ updates	L3 Managers and Technical POCs	Informal text of monthly progress - indicate "None" for negative replies *e-mail text; web-site entry*	Unless significant progress is reported, can be brief
Quarterly Progress	Quarterly	Program Management Council (PMC)	L2 Managers	Text (and accompanying graphic, if any) of quarterly progress towards L1/L2 milestones *e-mail text; electronic copy of graphic; web site entry (under development)*	Progress towards all active L2/L3 milestones should be reported
Technical Highlights	Quarterly	Program advocacy and reviews	L2 Managers	One page text (Bullets: Objective, Background, Accomplishment, Future Plans) and one page graphic *e-mail text; electronic copy of graphic; web site entry (under development)*	Technical Highlights are used to promote the CICT Program and represent significant accomplishments
Milestone Summaries	Milestone due dates or completion	Program advocacy and reviews	L2 Managers	Detail description of milestone accomplishments relative to goals and success metrics. Background material including graphics, technical reports, publications, etc. *e-mail text, electronic copies of graphics, hardcopies of reports*	
Budget and Workforce Tracking	Monthly (5th working day of each month)	Status reports to ITSRPO and CFO	Center POCs for resource management	Spreadsheets, graphs at the 5-digit level. Include variance explanation for +/- 10% variances *e-mail text; electronic copy of graphs; web site entry (under development)*	Planned vs. actual commitments obligations and accruals at 5-digit level. Planned vs. actual CS and SSC workforce.
ASTAC Sub-committee Reviews	Annual	To review and provide advice on research efforts	L1, L2, and L3 Managers and Technical POC's	Program, project, and sub-project plan on-site review on status, approach, and technical accomplishments	
LCPMC	Annual	To review status, budget, and milestones	L1 and L2 Managers	Program and Project tracking of budget and milestones	

14 RELATIONSHIPS TO OTHER PROGRAMS AND/OR PROJECTS

Formal relationships to other Programs and/or Projects are defined by NASA agreements (MOU's, MOA's, Grants, Contracts, Cooperative Agreements, and Letters of Intent). Details of relationships and expectations of other Programs and organizations are explicitly defined in those agreements (see AGREEMENTS section), and subject to the formal NASA review and approval process.

15 TECHNOLOGY ASSESSMENT

Technology assessment is performed through internal and external reviews (see INDEPENDENT REVIEWS section) over the duration of performance.

16 COMMERCIALIZATION OPPORTUNITIES

Communicating knowledge is considered a significant charter of NASA's mission. The responsibility for communicating knowledge and for Education Outreach related to this sub-project will also reside at the task level. Plans for communicating results to the public and to provide education will be coordinated with Center Public Affairs, Commercialization, and Education offices. It is vitally important to the success of the program that information about research and associated activities be made readily available to the public. Innovative flight projects will command the attention of NASA supporters and the public in general. This public interest will offer excellent opportunities not only to demonstrate the value of research to society, but also to provide unique support for formal and informal education. The sub-project actively supports the NASA performance plan commitment to involve the educational community in our endeavors to inspire America's students, create learning opportunities, and enlighten inquisitive minds. In consultation with the Office of Public Affairs, Commercialization, and Education (PACE), the sub-project will develop an education outreach plan, which includes and results in educational products. These products will fit within NASA's education Program and evaluation Framework as outlined in the NASA Implementation Plan for Education. They will be consistent with and directly linked to current educational standards and will use program content to demonstrate or enhance suitable learning objectives.

These products will also be consistent with the CICT Educational Philosophy, described at: http://www.cict.nasa.gov/ed_philosophy.php. The technical innovations produced by CICT will be relied on for decades to come--yet where are the personnel who will use, adapt, integrate and interpret these products in the years ahead? Right now they are in elementary and middle school. The CICT Education effort will enhance the value of the CICT Program by providing tomorrow's generation of innovators with exposure to the specifics of CICT technology. Our investment in today's youth will pay dividends for decades to come.

CICT will develop educational outreach products that are focused on achieving the following results:

1. Increased student interest in science, mathematics, engineering and technology careers
2. Exposure and experience with emerging technologies for educators and students
3. Increased access to NASA information for students
4. Technological products and services that enhance the educational process
5. Opportunities for Inter-Agency collaboration in educational technology

17 DATA MANAGEMENT

The transfer of technology including software, data, technical reports and publications will be subject to Export Control, as defined in part 121-1 of the International Traffic in Arms Regulations (ITAR) and the Military Critical Technologies List (MCTL). The IFCS Project Office will consult with the Export Control office before responding to any request for software and data, and prior to the dissemination of technical reports and publications in order to insure compliance with both ITAR and MCTL technology transfer restrictions, policies, and practices. Direct contracts of R&D and agreements with industry and other government agencies will be employed. The tasks fund R&D contracts and cooperative agreements and grants that ensure direct transfer of technology to U.S. industry insuring the likelihood of transfer into customer products. Technology exchange also occurs among the participants through special technical working group meetings, plant visit / briefings and technical society meetings.

18 LOGISTICS

The ICD and NeMC Sub-Projects fully comply with all logistics requirements defined in the Project Plan. Logistics associated with in-flight validation of milestones 8.4 and 8.6 will be in full compliance with NASA Dryden institutional requirements leading up to, and including the Airworthiness and Flight Safety Review Board (AFSRB).

19 TEST AND VERIFICATION

The ICD and NeMC Sub-Projects fully comply with test and verification procedures defined in the document 53.ARC.0009.2.1, and procedures for ARC310 and NF1676.

Appendix A Glossary

ARC	Ames Research Center
ASET	Automated Software Engineering Technologies
ATAC	Aerospace Technology Advisory Committee
BN	Bio-Nanotechnology
CAN	Cooperative Agreement Notice
CICT	Computing, Information, and Communications Technologies
CNIS	Computing, Networking and Information Systems Project
DARPA	Defense Advanced Research Projects Agency
DoD	Department of Defense
ECS	Engineering for Complex Systems
EEG	Electroencephalogram
EMG	Electromyogram
ES	Evolvable Systems
FAA	Federal Aviation Administration
FTE	Full Time Equivalent
FY	Fiscal Year
HW	HealthWatch
ICD	Intelligent Controls and Diagnostics
ICHM	Integrated Control and Health Monitoring
IFC	Intelligent Flight Control
IHASM	Intelligent Health and Safety Monitoring
ILEC	Intelligent Life Extending Control
IS	Intelligent Systems Project
IT	Information Technology
ITSR	Information Technology Strategic Research
JPL	Jet Propulsion Laboratory
MOA	Memorandum of Agreement
MSM	Mission and Science Measurement Technology
NASA	National Aeronautics and Space Administration
NeMC	NeuroElectric Machine Control
NPG	NASA Procedures and Guidelines
NRA	NASA Research Announcement
NRC	National Research Council
OAT	Office of Aerospace Technology
PCHM	Propulsion Control and Health Monitoring
PDR	Preliminary Design Review
PMC	Program Management Committee
RCA	Revolutionary Computing Algorithms
RFP	Request for Proposal
TRL	Technology Readiness Level
TRR	Technology Readiness Review
UPN	Uniform Program Number

URETI	University Research Engineering and Technology Institute
WBS	Work Breakdown Structure

Appendix B Change Log

Date	Content	Changes
September 2001	ICD Sub-Project Plan FY02	
September 2002	ICD IBPD FY03	
July 2003	ICD and NeMC IBPD FY04	
September 2003	ICD and NeMC Sub-Project Plan FY04	